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# AN ANALYSIS OF BEEF CATTLE FEEDLOT DESIGNS FOR POLLUTION CONTROL


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# AN ANALYSIS OF BEEF CATTLE FEEDLOT DESIGNS FOR POLLUTION CONTROL

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Production of beef in the United States is increasing at a greater rate than the population increase because people are eating more meat. Over 200 million people in the United States consume 114 pounds of beef per person annually compared with about 60 pounds in the 1950's. Over 23 billion pounds of beef are required annually to maintain our present level of beef consumption (6).<sup>2</sup>

Cattle feeding is an "industry" with a high degree of specialization and intensification. High concentrations of livestock have placed the feeding industry in the public eye as a potential pollution threat to the environment. An efficiently operated outdoor feedlot must be well drained. Unfortunately many well-drained sites are close to waterways or directly above a stream. The public became aware of

potential pollution from feedlots when fish kills occurred, mainly in Kansas. Communities that have grown around feedlots complained about odors, dust, and other nuisances.

Many factors must be blended together in designing a feasible feedlot operation that will produce good animal gains and control all wastes including surface runoff, ground water contamination, and such nuisances as odors, flies, and dust. Complaints lodged against a feedlot operator can cause an immediate reaction that may result in a poorly designed facility. Before a decision is made, various alternatives available to the feedlot operator should be analyzed to insure fulfillment of long-range goals. The many criteria to be considered should be thoroughly analyzed by feedlot operators before undertaking a runoff-control program.

## WASTE MANAGEMENT ALTERNATIVES

The method of manure management for a given production scheme will vary considerably with the cattle densities applied to the land area. Quantity of excreta defecated on an acre of feedlot varies significantly with the cattle density and size (table 1). A given management scheme is a function of the manure accumulation and resulting surface conditions. Some operators prefer to feed small cattle starting at about 400 to 500 pounds and feed them to about 800 pounds. Daily production of solids per animal will be 34 to 38 percent greater for cattle fed to finish at 1,000 pounds than for

cattle fed to 800 pounds.

The calculated data in table 1 do not indicate the actual quantities of waste removed from a feedlot under the various management schemes. Gilbertson et al. (2) reported that material removed from unpaved feedlots of different slopes and densities contains a very significant amount of soil. Dry matter removed was up to 5.7 times greater than the dry matter estimated reaching the lot in the form of feces. The extra material (soil) must be moved twice. First, extra weight must be carried from the feedlot for field disposal. Second, high-use areas must be refilled requiring additional expenditures for hauling soil back into the feedlot.

The feedlot operator actually has greatly increased the cost of maintaining the feedlot surface in a "good" condition. He has accepted

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<sup>2</sup> Italicized numbers in parentheses refer to Literature Cited at the end of this report.

Table 1.—Estimated waste production in cattle feedlot under alternate management schemes<sup>1</sup>

Management scheme	Waste production per acre					
	Cattle per acre	Excreta	Feces	Urine	Solids	Average solids production per day
	Number	Tons	Tons	Tons	Tons	Tons
Unpaved feedlots with indicated slope (percent):	500-pound animals, 180-day feeding, 1,000-pound final weight					
0-3 .....	100	418	292	125	44	0.24
4-6 .....	175	731	512	219	77	.43
7-10 .....	220	919	644	274	96	.54
Paved feedlots, 55 sq. ft. per head .....	800	3,344	2,344	1,003	352	1.95
Housed feedlots with indicated area per head (sq. ft.):						
25 .....	1,750	7,310	5,120	2,190	766	4.26
20 .....	2,200	9,190	6,440	2,758	960	5.36
Unpaved feedlots with indicated slope (percent):	800-pound animals, 80-day feeding, 1,000-pound final weight					
0-3 .....	100	216	151	65	23	.29
4-6 .....	175	377	263	114	40	.50
7-10 .....	220	474	332	142	50	.63
Paved feedlots, 55 sq. ft. per head .....	800	1,728	1,208	520	184	2.30
Housed feedlots with indicated area per head (sq. ft.):						
25 .....	1,750	3,775	2,630	1,140	396	4.95
20 .....	2,200	4,740	3,320	1,423	500	6.23
Unpaved feedlots with indicated slope (percent):	550-pound animals, 100-day feeding, 800-pound final weight					
0-3 .....	100	202	141	60	21	.21
4-6 .....	175	354	249	105	37	.37
7-10 .....	220	445	312	132	46	.46
Paved feedlots, 55 sq. ft. per head .....	800	1,616	1,136	480	168	1.68
Housed feedlots with indicated area per head (sq. ft.):						
25 .....	1,750	3,535	2,490	1,050	370	3.70
20 .....	2,200	4,450	3,120	1,320	460	4.62

<sup>1</sup> Data based on Loehr (4). Daily waste production estimated as follows: Excreta = animal weight x 0.06;

feces = excreta x 0.70; solids = manure x 0.15.

any method that fulfilled the need for adequate animal gains. Such high-use areas as those adjacent to the feed bunk and around the livestock waterers are cleaned intermittently as needed. Manure mounding is definitely recommended since biological activities will oxidize part of the manure and thus reduce the overall cost of maintaining the feedlot since transportation is eliminated. The manure mounds also provide an area where animals can get out of the mud during wet conditions.

Critical problems facing the feeder at this time are runoff and odor control from outdoor feedlots (1). Preliminary research in Nebraska indicated that workable runoff-control facilities are possible.<sup>3</sup> Odor production on exposed feedlots will probably be the deciding

<sup>3</sup> Gilbertson, C. B., McCalla, T. M., Ellis, J. R., and Woods, W. R. Methods of removing settleable solids from outdoor beef cattle feedlot runoff. Amer. Soc. Agr. Engin. Paper No. 70-420, 37 pp. 1970. [Copy on file Agr. Engin. Dept., Univ. of Nebr., Lincoln.]

factor in terms of "cease and desist orders." The layout of exposed outdoor feedlots will make it difficult to mechanically control these odors.

Paved feedlots may be able to survive the economic pressures better than unpaved lots. Higher densities permit raising from 15 to 20 times as many cattle per acre on paved lots as on poorly drained unpaved lots. Smaller land areas reduce the volume requirement for the runoff-control facility. On the other hand, considerably more labor will be required to manage the manure. Daily to weekly scraping of the paved surface is necessary to keep the cattle clean. Labor required for the 1,000- to 2,000-head lots would be very costly.

Several waste-management alternatives are available to operators of housed feedlots. The formation of a manure pack has been used for years; however, high cost of bedding has made this method unpopular in some areas. Semi-annual cleaning in this system, however, does place labor requirements in a more opportune season in relation to other workloads.

Disposal of the waste is commonly accomplished by field spreading. Composting the material has been successful but is limited to larger operations since the equipment costs are relatively high. Composting may be done by placing the solids in windrows 5 to 6 feet deep and agitating once every 3 to 5 days (5). The process reduces the quantity of material that must be field spread or otherwise utilized.

Incinerating the waste is possible since the bedding material has actually reduced the manure moisture content. Incineration reduces the waste to a mineral mass. Nutritive values are lost, but only about 5 percent of the material remains to be handled. Costs and methods of incineration are not well documented for beef feedlot operations (5).

In most of the recent housed feedlots the slotted floor and concrete pit are used. Management of wastes within a housed feedlot was originally accomplished by constructing an 8-foot-deep pit that would hold about 6 months' storage of manure beneath the slotted floor. Removal of the manure slurry was difficult, principally the sludge accumulation from the pit. With new developments in equipment design, however, many problems of agitation and removal are overcome.

Storage of manure in pits for up to 6 months has the disadvantage of high odor production and possible noxious gas formation. The slurry beneath the slats is a putrefied mass. When this mass is field spread, the odors last for a week to several weeks depending on climatic conditions. Detention periods were used originally to refrain from field distribution during adverse weather. Regulations are also under consideration in some States that would prohibit the spreading of manure on frozen fields. Installing a reuse pit on the lower side of the disposal field to reduce spring thaw runoff would eliminate this pollution threat.

To reduce the odor problem, some operators use oxidation ditches, which operate at depths of about 30 inches and are located below the slotted floor. Initially they should be filled with fresh water. Cattle are admitted to the environment slowly to allow time for the growth of biological organisms required for digestion of the wastes in the oxidation ditch. If ditches are operated continuously, addition of water is required to maintain overflow, which in turn maintains the optimum solids content. The overflow can be stored in a holding pond outside the structure. Operators use a constant overflow on the watering stations, direct dilution of the manure with water from the domestic water supply, or reuse from the holding pond. The oxidation ditch affords an excellent means of odor control and the potential for biological degradation of 50 percent of the solids for beef cattle feedlots (3). The liquid stored in the holding pond must be field spread by irrigation techniques or the pond must be large enough to allow for evaporation.

Another method used for housed feedlots is mechanical scraping of the pit to remove manure daily or at the discretion of the operator. Daily removal and daily spreading would appear to be more advantageous than holding the droppings for longer periods because of the decreased odor within the structure. Daily removal of manure from the pit has good potential as a recommended practice. Harmful gaseous production would be eliminated within the structure; however, a manure storage area adjacent to the housed feedlot or daily spreading would be necessary.

In general, the housed feedlots have eliminated the "runoff" problem from the feedlot

itself. Odor control has also been placed in a "feasible" category. Odors may be produced, but they are confined to an area sheltered from the wind. Therefore the odor-laden air may be moved mechanically to where it may be "treated" before release from the structure.

Housed feedlots may be much more numerous within the next few years, even though

outdoor feedlots will continue to be an economically important management alternative for operators. "Treatment" of the beef wastes in the future may imply the biological transformation of the wastes into a byproduct. Biological activities combined with mechanical processing may allow beef feeders the opportunity to merchandise a usable product.

## ALTERNATE SCHEMES AVAILABLE FOR BEEF PRODUCERS

Three basic alternate management schemes available for beef producers are given in table 2. Several factors must be considered before final decisions can be made concerning the selected scheme. Historically beef has been produced on land of varying topography. Operators have been reluctant to "reshape" the feedlot site to uniform grades unless extreme conditions existed. Feed preparation, feed delivery, and nutritional needs have been emphasized because research information has

indicated that a low cost-to-benefit ratio is the result of careful nutritional planning. A cost-to-benefit ratio is not readily available for the planning and preparation of the site. Labor shortages and pollution implications have prompted the need for proper initial planning of the physical facilities.

The management schemes in table 2 are based on physical design and long-term implications dictated by pollution-control regulations.

Table 2.—Animal density for alternate management schemes of beef production

Scheme	Animal density	
	Sq. ft. per head <sup>1</sup>	Animals per acre <sup>2</sup>
Unpaved feedlots with indicated slope (percent):		
0-3 (poor drainage) . . . . .	400 and up	100
4-6 (adequate drainage) . . . . .	250 and up	175
7-10 (good drainage) . . . . .	200 and up	220
> 10 (not recommended) . . . . .	---	---
Paved feedlots . . . . .	55	800
Housed feedlots:		
Partial shelter (open unpaved shed with access to outside paved or nonpaved lots) . . . .	( <sup>3</sup> )	( <sup>3</sup> )
"Cold house" (open shed without access to outside):		
Manure pack . . . . .	30	1,450
Slotted floor . . . . .	20	2,200
"Warm house" (totally enclosed, environmentally controlled) . . . . .	20	2,200

<sup>1</sup> Areas are net design areas; feed alleys, working alleys, corrals, and so forth, require additional space.

<sup>2</sup> These are design data that indicate the maximum densities of heavy cattle for "average" conditions.

<sup>3</sup> See animal density for unpaved and paved feedlots; 30 square feet per animal allowed within shelter plus outside allowance.

## PHYSICAL REQUIREMENTS OF FEEDLOT ALTERNATIVES

Major considerations for developing an unpaved feedlot are as follows: (1) Shaping an all-weather feed alley; (2) reshaping topography to obtain adequate drainage; (3) diversion of outside runoff water; (4) area required for a runoff-control facility; and (5) area for disposal of controlled runoff and manure accumulation.

The feed bunks should be oriented to the north-south or northeast-southwest direction. An eastern slope will fulfill this requirement. East-west oriented bunks will result in an ice buildup on the north side during freezing periods and snow accumulations during winter storms. A 10-foot concrete apron is recommended for the full feed-bunk length and around all watering stations.

The design capacity for unpaved lots is determined by the feedlot slope and climatic conditions. In general, the number of animals that can be fed on an acre of land will vary from 100 to 250 depending on the land slope. Slopes of less than 3 percent are not recommended because poor drainage results in muddy conditions. Muddy surface conditions can depress animal gains significantly.<sup>4</sup> Slopes greater than 10 percent are not recommended because they often accelerate erosion problems. The number of cattle actually in a feedlot at a given time will vary with cattle availability and the season. Spring thaws, for example, result in muddy conditions that can place stress on cattle. Feedlot operators increase the area per animal to improve surface conditions by removing cattle and placing them on pasture or in temporary holding facilities. Operators of unpaved feedlots must be prepared to alter their management scheme depending on the surface condition of the feedlot.

Paved feedlots have not been generally accepted by beef producers. High labor requirements necessary to maintain clean cattle, cold surface conditions during the winter, and hot surfaces during the summer are the major objections to this system.

A paved feedlot site should be graded to a minimum of 2-percent slope. About 800 head

of cattle per acre is a generally accepted density for design purposes on paved lots. Feed-bunk space will vary from 0.5 to 1 foot per head depending on a single or multiple daily feeding interval. This is in contrast to unpaved feedlots where feed-bunk space varies from 1 to 2 feet per head and cattle are fed once daily.

The main advantage of paved feedlots is the increased number of animals produced per unit area and the potential for greater mechanization of the feed distribution.

Providing shelter for beef cattle is not new to some livestock feeders. A covered shelter has been an accepted requirement in northern climates for many years. The partial shelter is available to allow cattle a resting area during severe climatic conditions. The feedlot is operated in the same general manner as unpaved lots or paved lots without shelter. A bedded manure pack is usually provided within the sheltered area. A shelter space of 30 square feet per animal is suggested as a minimum in addition to the area allowed outdoors. Areas indicated in tables 1 and 2 for unpaved and paved feedlots would be design values for open lots and available shelter.

There is considerable interest in feeding cattle within a completely housed arrangement, where over 20 times as many cattle can be produced on the same area as compared with those produced on unpaved lots on relatively flat slopes. The need for construction, operation, and maintenance of a runoff-control facility is eliminated. There are two basic designs for a housed feedlot—completely enclosed, environmentally controlled units (warm house) and open-front units (cold house). The open-front noninsulated housing is the more popular. Environmentally controlled units are not generally accepted since experiments with various types of housing have shown that cattle performance is not greatly affected until climatic conditions are extreme.<sup>5</sup>

Waste-management methods used by operators for the various management schemes are as follows:

<sup>4</sup> Bond, T. E., Garrett, W. N., Givens, R. L., and Morrison, S. R. Comparative effects of mud, wind, and rain on beef cattle performance. Amer. Soc. Agr. Engin. Paper No. 70-406, 9 pp. 1970. [Copy on file Agr. Engin. Dept., Univ. of Calif., Davis.]

<sup>5</sup> Self, H. L. Structures: The base for livestock production. Amer. Soc. Agr. Engin. Paper No. 69-908. 1969. [Copy on file Anim. Sci. Dept., Iowa State Univ., Ames.]

Unpaved feedlots:

Solids accumulation .....	Manure mounded within lot; biannual manure removal; intermittent cleaning of high-use areas; cattle density reduced to decrease manure accumulation.
Runoff .....	Runoff-control facility: Settleable solids removal; liquid detention; disposal of liquids by irrigation techniques; outside drainage diverted.

Paved feedlots:

Solids accumulation .....	Daily scraping of lot area to aboveground stockpile; accumulation field spread with conventional spreader. Daily scraping of lot area to concrete manure pit; liquid manure field spread as required with special pumping equipment.
Runoff .....	For manure stockpiling concept, runoff-control facility as indicated for "unpaved feedlots" is required. For manure tank method, volume designed to control runoff within same tank.

Housed feedlots:

Partial shelter, access to outdoor lots:

Solids accumulation .....	Manure pack within dirt-floor shelter; semiannual cleaning. For outdoor area, see "unpaved feedlots" and "paved feedlots."
Runoff .....	Rooftop runoff diverted; feedlot runoff controlled as for "unpaved feedlots" and "paved feedlots."

"Cold house":

Solids accumulation .....	<i>Concrete floor:</i> Daily scraping into stockpile or concrete tank; manure pack with bedding; composting or incineration may be used to reduce volume of material to be handled. <i>Slotted floor:</i> Deep-pit storage pumped out as required (up to 6 months' storage); oxidation ditch; shallow pit with daily removal to outdoor storage tanks; pit with mechanical scrapers; manure stockpiled or daily disposal to field with manure spreader; dehydration or incineration of manure to reduce volume of material handled.
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"Cold house" and "warm house":

Runoff .....	None required.
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## INITIAL COST OF VARIOUS FEEDLOT MANAGEMENT SCHEMES

One of the more important factors for the feedlot operator is the initial cost, which normally is overweighted by individuals; however, it is essential in establishing a basic format. Material costs and labor costs are subject to local conditions and will have a major effect on the initial cost of a given management scheme.

The first step in setting up a cost comparison is to determine the type of construction. Various materials are available for feedlot construction and they affect initial costs. Labor costs must be added for the final initial-cost estimates. The construction alternatives for various components of the feedlot facility are as follows:

<i>Component</i>	<i>Construction alternative</i>
Concrete .....	Ready-mix; cement and gravel purchased, own concrete mixed.
Feed bunk .....	Wood, wood and concrete, or all concrete.
Feedlot fence.....	Wood (4 and 5 rows), wire rope (4 and 5 rows), wire mesh, barbed wire with electric wire, or windbreak fence.
Gates .....	Wood or metal.
Watering station.....	Concrete base and automatic waterers (electric, gas, or constant overflow type).
Feedlot surface .....	Hard surface (concrete or asphalt) or unpaved (earthwork required to obtain good drainage).
Feed road.....	Paved or graveled.
Housing .....	Partial shelter or totally confined ("warm house" or "cold house").

The water system installation cost depends on the length of pipe required and trenching costs. Runoff control is required for outdoor lots only.

The next step is to establish comparative costs for the alternate management schemes available. Only the comparable items should be listed. The approximate costs of feedlot materials for these schemes are as follows:

<i>Alternate management scheme</i>	<i>Estimated materials cost per 1,000 head<sup>1</sup></i>
Unpaved feedlots with indicated slope (percent):	
0-3 .....	\$27,100
4-6 .....	23,900
7-10 .....	20,700
Paved feedlots <sup>2</sup> .....	19,700
Housed feedlots with indicated area per head (sq. ft.):	
30 .....	<sup>3</sup> 64,100
20 .....	<sup>4</sup> 57,800
	<sup>5</sup> 69,800

<sup>1</sup> The following materials costs were used in estimates: Land \$500 per acre; feed bunks, \$3.50 per foot; fence, \$1.26 per foot; gates, \$47.50 each; plastic water pipe, \$0.75 per foot; concrete, \$0.25 per square foot; gravel feed road, \$1.19 per foot; runoff-control facility, \$500 per acre of drainage.

<sup>2</sup> Cost of runoff-control facility is included for outdoor lots only; costs do not include insulation of shelters.

<sup>3</sup> Total cost includes 6-inch concrete floor and manure-pack management.

<sup>4</sup> Total cost includes slotted floor with 8-foot-deep pit.

<sup>5</sup> Total cost includes slotted floor with 4-foot-deep oxidation ditch.

Cost for a feed-mixing plant, working corral, and waterer is assumed to be a requirement for all feedlot operations and is not included since it would be the same for each of the listed schemes. The unpaved and paved (concrete) feedlots are similar in initial cost. It must be pointed out, however, that some of the cost savings for the initial materials with the paved lots will be partially offset by additional management and labor requirements throughout a year's feeding period. As an example, the concrete lots must be scraped frequently to maintain clean cattle and good animal gains. Also, if feed-bunk space of 6 inches per head is allowed, more than once-a-day feeding is required. It is necessary to maintain feed within the feed bunk at all times when sufficient space is not available for all the animals to be at the feed bunk at one time.

The cost indicated in the last tabulation for the concrete feedlot provides for runoff control only. Allowances were not made for daily accumulation of solids within the runoff-control facility. It was assumed that solids removed from the feedlot area are field spread as the lots are cleaned.

The total initial cost of a housed feeding unit will vary depending on the type of waste management and the area allowed per animal unit. About 50 to 60 percent of the initial cost of such a unit is in the structure itself. Confining the animals to 20 square feet per head

rather than to the 30 square feet in an open-front building reduces the cost by about 40 percent. The recommended practice a few years ago was to allow larger areas for open-shed structures than environmentally controlled units. Recently the trend has been to confine the animals in slotted-floor, open-front structures at 20 square feet per head. The 30-square-feet-per-head unit is normally used where there is a manure pack. Unavailability of bedding and the high labor requirements have caused many operators to reject this particular type of system.

The cost of a housed feedlot is affected by the method of manure management. Using the 4-foot instead of the 8-foot-deep pit makes little difference. The 4-foot pit, however, does adapt to the "oxidation ditch" principle. The initial cost of a housed feeding unit would be increased by about \$2,000 per 100-head animal

capacity when the oxidation ditch is used. Effluent from the oxidation ditch must be detained within a holding pond or be field spread. A detention pond is necessary in colder climates where frozen conditions persist for extended periods. Cost for the outside holding pond is not included in the last tabulation. Operating costs for the oxidation wheel are high. Approximately 10 horsepower is required for each 100 animals within a confined structure. Annual operating costs per 100 head would be approximately \$1,750 at 2 cents per kilowatt-hour.

Initial costs are required for comparing various beef cattle feedlot production methods. The initial cost, however, must be supplemented with probable hidden costs, which include increased management or labor for a given alternative. The operator must weigh all factors before making a logical choice.

## SUMMARY

(1) The management schemes available to the feedlot operator are unpaved, paved, and housed feedlots.

(2) Odor problems will limit outdoor commercial feedlot development as a management scheme in populated or recreation areas.

(3) High labor requirements for manure management and apparent cattle discomfort may limit development of outdoor paved lots.

(4) Housed feeding will become more popular with beef producers as labor shortages and pollution problems increase.

(5) High labor and high bedding costs re-

tard the potential development of feedlots using the manure-pack management scheme.

(6) There is little difference between the overall materials cost of paved and unpaved feedlots.

(7) For a housed feeding unit, the cost of the structure is about 50 percent of the total materials costs.

(8) Use of an oxidation ditch with a housed feedlot increases the initial materials cost by about 17-20 percent. Annual electricity costs for operating the oxidation wheel will be approximately \$1,750 per 100 head of capacity.

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